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USAARL REPORT NO. 71-13

THE USE OF HIGH INTENSITY XENON LIGHTING TO ENHANCE
U. S. ARMY AIRCRAFT DAY/NIGHT CONSPICUITY

By

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JANUARY 1971

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama



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ABSTRACT

In-flight studies were performed at Fort Wolters, Texas, to compare the effectiveness of aircraft-mounted, high-intensity xenon flashtube lights for increasing the conspicuity of small trainer helicopters (TH-55) during both daytime and nighttime flights. Twenty-eight subjects rated both lighted and non-lighted aircraft visibility as viewed from the ground and from air to air in differing flight modes. Data are presented to indicate the increase in aircraft conspicuity available through the application of this type of lighting.

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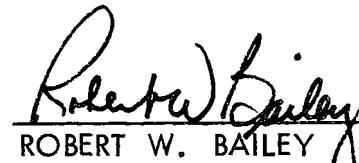

ROBERT W. BAILEY
COL, MSC
Commanding

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THE USE OF HIGH INTENSITY XENON LIGHTING TO ENHANCE U. S. ARMY AIRCRAFT DAY/NIGHT CONSPICUITY

INTRODUCTION

The ever-present threat of a mid-air collision is a problem that confronts every aviator, whether he flies a large commercial airliner or a small, fixed or rotary wing aircraft. As the numbers of aircraft in a given air space increase, the probability of a collision correspondingly increases.

The role of aviation in the U. S. Army has expanded considerably in the last few years. The extensive use of rotary wing aircraft in all phases of warfare, particularly in Vietnam, has been primarily responsible for this rapid increase.

The flight characteristics of vertical take-off and landing (VTOL) and vertical, short take-off and landing (V/STOL) aircraft are significantly different from those of fixed wing and tend to magnify the problems of collision avoidance for the Army aviator.

There are three primary methods which can be utilized for preventing mid-air collisions. These are:

a. Complete air traffic control, e. g., instrument flight rules and a radar system necessary for complete control of airspace.

b. Complex, aircraft-mounted electronic equipment designed to provide an automatic station-keeping capability, or a less complicated system to warn of the presence of other aircraft in the vicinity. Concentrated effort on the part of several agencies at Fort Rucker, Alabama has resulted in the design and procurement of a proximity warning device. This system provides some measure of visual and aural warning should two aircraft equipped with the device approach within a specified distance. It does not, however, presently

incorporate azimuth or approach direction.

c. Visual warning.

Training, enforcement of proper procedures, etc. can be a supplement to these control methods.

This Laboratory has been conducting research in the realm of mid-air collision avoidance for several years. After careful consideration of the many parameters involved, it was decided that visual warning was a major area that had not been sufficiently investigated, especially since the Army functions primarily under visual flight rules that require vigilant application of the "see and be seen" concept of collision avoidance.

Throughout his entire career, the Army aviator is repeatedly warned that he must remain visually alert for other aircraft while performing his flight mission. Yet, in spite of the emphasis placed upon this important aspect of flying, aircraft continue to collide most often under ideal visibility conditions.¹

There are several important factors which contribute to the failure of pilots to see and avoid other aircraft. These are:

- a. Visibility restrictions imposed by the design of the aircraft. These include structural blockage; windscreens slant, color, and configuration; seating position; and glare and reflections, to name a few.
- b. The presence of scratches, bugs, and dirt on the windscreens.
- c. Cockpit preoccupation with navigational aids or charts during normal cross-country flights or missions.
- d. Cockpit preoccupation associated with instrument training, in which the extra-cockpit vision of the student is mechanically blocked and the instructor pilot is tasked to monitor the student and the instruments, in addition to visually clearing the airspace.
- e. Reduced visibility due to weather or, as an ever-increasing problem, the presence of smog.
- f. Time of day, particularly when sun angles cause veiling glare and convert scratched windscreens into translucent screens.

- g. Aircraft vibration.
- h. Low contrast and/or silhouette of other aircraft.
- i. Reduced vigilance due to fatigue, discomfort or malaise. This is a problem that could be expected to occur more frequently in the combat zone.
- j. Space myopia: - The human eye, while viewing an unstructured field, tends to focus at approximately one to two meters.²
- k. Inadequate scanning patterns: - To be completely safe, it is estimated that the pilot must scan his surroundings completely in both direction and depth at a repetition rate on the order of ten times per minute. The problem of fixation tendency can be avoided with proper scanning technique.
- l. Inattentiveness: - The pilot, on a dull or ordinary mission such as a routine cross-country flight, will allow his thoughts to be diverted to something other than the act of flying.
- m. Reduced illumination: - Flights conducted at periods of dawn or dusk or during marginal weather conditions require extra vigilance.
- n. High ambient light: - The use of proper sunglasses eases the discomfort associated with bright sunlight, although there is still a problem when the intruder aircraft is masked by the sun.

An extensive study³ pertaining to commercial aviation has revealed some interesting facts about time-sharing in the cockpit. External vigilance, which involves looking outside for other aircraft, approach lights, the runway and other objects, occupied only twenty-two percent of the crew's time. This study also recorded all Air Traffic Control-called traffic on 944 flight segments (approximately 1500 calls). These data represent the judgment of experienced and professional radar observers regarding potential collision hazards. It was found that fifty-eight percent of the Air Traffic Control-called traffic was never located by the alerted flight crew. The primary reasons for this occurring are:

- a. Some of the traffic could be in, above or below an intervening cloud deck;
- b. Poor scanning techniques, especially in periods of increased cockpit workloads during which pilots tend to clear only their own altitude and the

forward area;

- c. No vertical component for some radar tracking stations; and
- d. Perhaps most important is the poor conspicuity of the intruder aircraft.

Visual warning during daytime operations can be accomplished by exterior lighting mounted on the aircraft, and/or conspicuous paint or tape schemes applied to the exterior of the aircraft. Previous in-flight studies^{4, 5} by this Laboratory have demonstrated the feasibility of painted rotor blades as a means of enhancing the visibility of helicopters. Other investigations (data unpublished) concerning the judicious use of external paints and tapes for enhancing aircraft conspicuity have shown that:

a. Of the paints available, the most effective is the fluorescent type. However, the useful "life" of this paint is only three to six months. The application time, paint cost, and required "down-time" of the aircraft make this a very expensive program to maintain. The tendency of this paint to soften when exposed to certain oils and lubricants also causes serious problems due to paint creep and dirt entrapment.

b. Fluorescent tape, especially a recently-developed type having a useful "life" of thirty-six to forty-eight months, can be quite effective when applied to the aircraft exterior. There are limitations to placement, since the tape does not conform well to curved or irregular surfaces or to high rivets. In addition, tape cannot be applied to main rotors, tail rotors or propellers due to the inadequacy of adhesives and potential modification of the airfoil.

c. Whether tapes or paints are used, the overall effectiveness is directly related to the ability to "mass" the color on the aircraft, rather than apply small, scattered patches.

d. Small helicopters, such as the TH-13, LOH-6A, TH-55, LOH-58A, and the OH-23, characteristically have a limited fuselage area and thereby afford a poor silhouette for viewing. Since there is such a reduced area for the placement of tape or paint, the value of high visibility markings for these aircraft, other than the main rotor blades, is questionable.

Initial efforts concerning the use of high intensity lighting as a means of improving aircraft conspicuity were conducted early in 1967. After considering

the relative merits of various lights, it was decided that the Xenon gas-filled discharge tube, commonly referred to as "strobe" lights, offered the greatest potential. This light is produced by converting the 28 VDC input current of the aircraft to AC current, increasing it to 400 volts, reconverting it back to DC, and storing it in a condenser. A trigger mechanism, timed to pulse at a prescribed rate (usually 50 or 60 times per minute), delivers this stored current to a metal band, called an ionizing strip, which runs along the outside of the tube. This high voltage (as much as 2400 volts) causes the Xenon gas to briefly convert to a plasma, which radiates a characteristic bright, blue-white light.

An analysis¹ of 56 mid-air collisions involving U. S. Army aircraft has shown that only 6 occurred during nighttime flight. At Fort Rucker, Alabama the last mid-air collision at night was in 1955. These data, in our opinion, do not indicate an increase in the safety of flight at night, but rather the conspicuity advantage gained by the anti-collision light contrasting against the night sky. These data also show that 90% of Army mid-air collisions occur in the daytime during periods of good visibility, but poor aircraft conspicuity.

Although the theoretical aspect of high intensity lighting for daytime use has been investigated^{6, 7, 8, 9, 10}, it has only been in the past few years that technology has provided a satisfactory system for airborne application. The first use of this type of lighting was for nighttime anti-collision purposes.

Following a review of the literature and consultations with several aircraft lighting manufacturers, a multi-output daytime lighting system was procured by this Laboratory for in-flight studies. The purpose of these studies was to establish the feasibility of this type of lighting for daytime aircraft conspicuity enhancement and to determine the optimum light output level. Since the majority of local mid-air collisions have involved the smaller helicopters, initial lighting design characteristics, such as weight, size, power drain, and avionics interference, were based upon the physical characteristics of these aircraft.

Analysis of informal flight studies indicated a need for a two lamp system with each lamp having both day and night capability (see Figure 1). It was decided to incorporate a Xenon nighttime lamp after consideration of the light-output characteristics of the present anti-collision beacon. Table I shows the minimum intensities for present anti-collision lights as specified in Federal Aviation Regulations (FAR), part 23, Paragraph 23.1401. The Federal Aviation Administration (FAA) has recently issued a Proposed Rule Change which raises the minimum intensity level of the anti-collision lights from 100 to 400 effective candela (Eff. Cd.) and also provides the option of white or red light at night. The

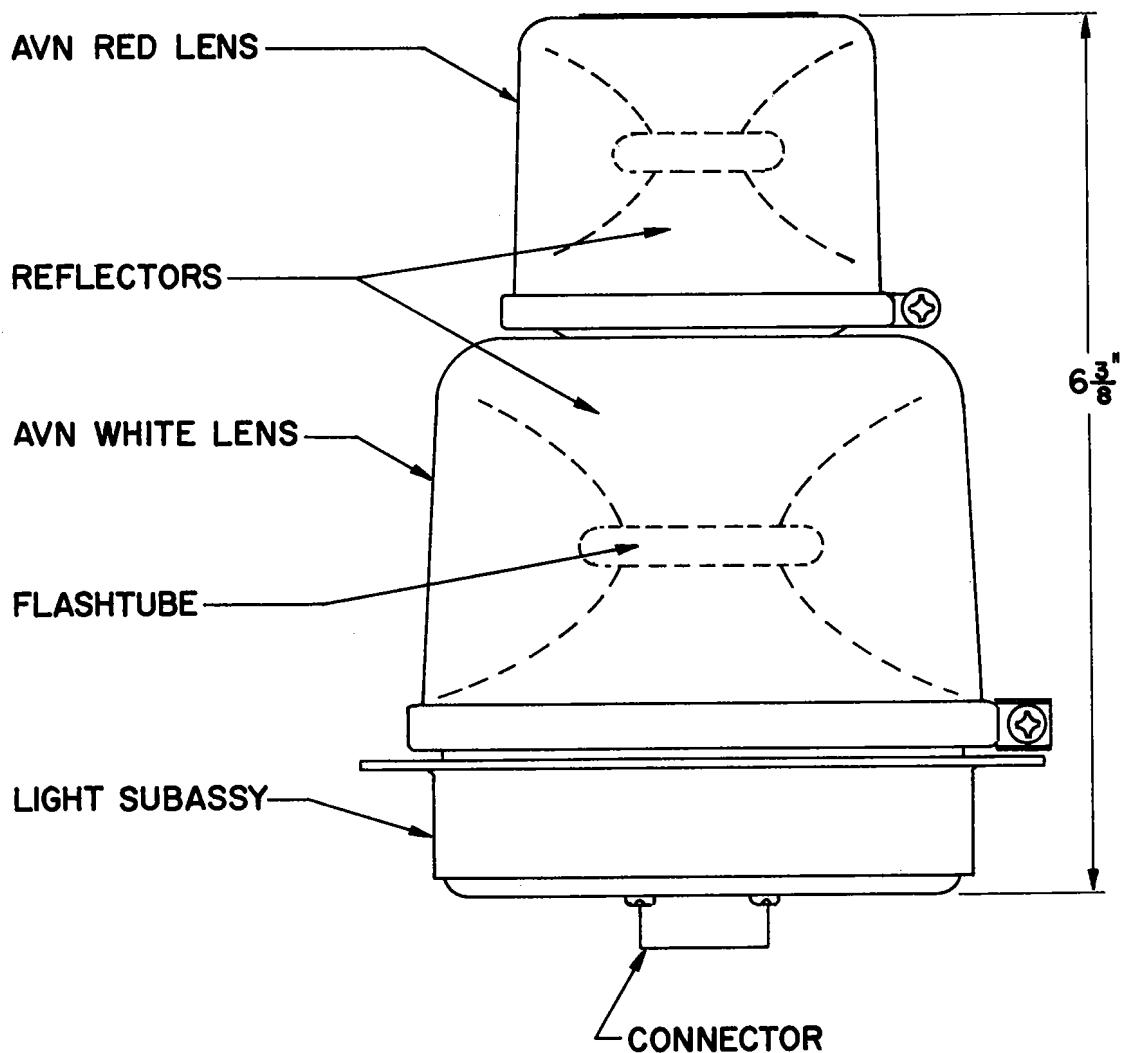


Figure 1.

One Lamp Design Which Combines Both Day (Clear) and Night (Red)
Capability in a Single Housing.

Table I

**Minimum Effective Intensities for Red Anti-Collision Lights
(FAR, Part 23, Paragraph 23.1401)**

<u>Angle Above or Below the Horizontal Plane</u>	<u>Effective Intensity (Candelas)</u>
0° to 5°	100
5° to 10°	60
10° to 20°	20
20° to 30°	10

present rotating red beacon is generally considered totally inadequate as a day-time anti-collision light, except perhaps under heavy, overcast skies or at dusk or dawn. At night, the rapid decrease in light output associated with eccentric viewing and the slow rise and decay of the flash make the beacon only marginally acceptable.

Although in-flight studies in 1967 and 1968 had demonstrated the feasibility of Xenon white lighting for daytime anti-collision purposes, no formal program had been undertaken to generate hard data concerning the psychophysical aspect of the system.

Through the cooperation of officials at the U. S. Army Primary Helicopter Center/School, Fort Wolters, Texas, this Laboratory conducted in-flight studies of a daytime multi-level lighting system mounted on the TH-55 (Hughes) helicopter. In addition, an off-the-shelf, white, Xenon lamp and a specially-designed Xenon lamp with a red shield were evaluated for use at night as a possible replacement for the present rotating anti-collision light.

METHODOLOGY

A. GROUND-TO-AIR OBSERVATION SEQUENCE (DAYTIME)

Equipment:

- 1) Field generator to provide 110 VAC;
- 2) 12" electric clock with sweep second hand;
- 3) Fixation target (3/4" white square) with stand;
- 4) Two TH-55 helicopters; and
- 5) Xenon-flashtube lighting system with three intensity settings of approximately 1800, 2300, and 3300 Eff. Cd.

Procedure:

The subjects were located on a pinnacle approximately 250 feet high and overlooking a valley (Figure 2). With the fixation target acting as the center of a partial circle, the subjects were seated approximately ten feet away from the fixation target and 15 degrees apart, right and left of the fixation target. There

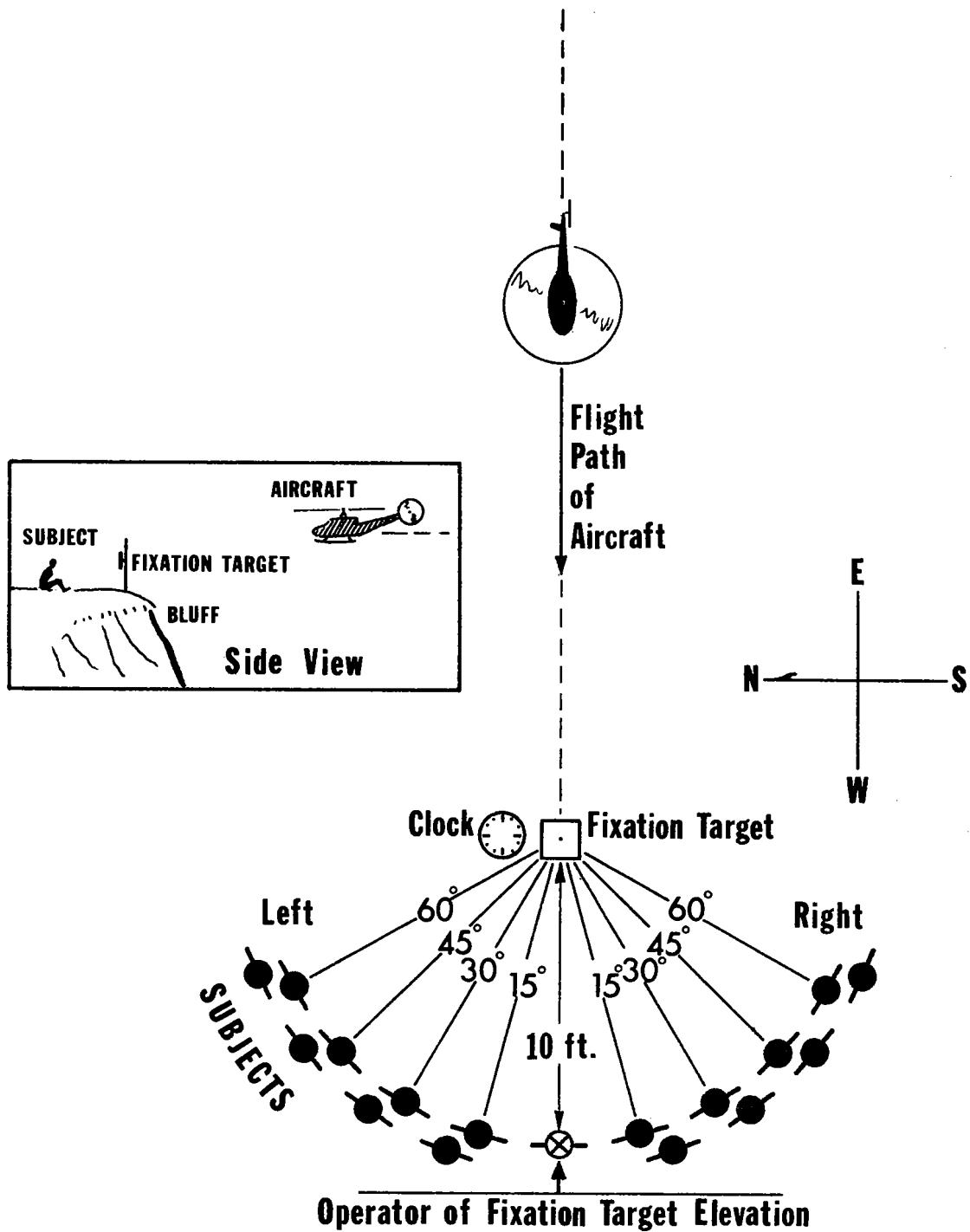


Figure 2.

Ground-to-Air Observation Sequence

were two subjects, one in front of the other, at each position. The positions of the subjects were designated as 15° left, 30° left, 45° left, 60° left, 15° right, 30° right, 45° right and 60° right. Right or Left referred to the direction the aircraft appeared to approach the subject. The Xenon light-equipped TH-55 and the standard TH-55 aircraft (with the standard rotating red anti-collision light operating) approached the pinnacle from the East, approximately four miles away, at 50 knots airspeed, and 30 feet below the pinnacle. The proper bearing and altitude of the aircraft were monitored and directed from the pinnacle by radio. The subjects were instructed to look only at the fixation target (3/4" white square on a black background). The fixation target was mounted on a vertical seven foot 2" x 4" board in such a manner that the target could be raised or lowered as the aircraft approached. This adjustment was necessary in order to keep the vertical visual axis aligned with the aircraft and to insure that the assigned horizontal visual angle between the fixation target and the approaching aircraft remained constant for each subject.

The intensity level on the strobe-equipped TH-55 was changed to one of three different settings on each pass. The standard-lighted TH-55 followed on the same flight path about three minutes behind the Xenon-equipped aircraft. This procedure was used on the morning of 22 September 1970 and afternoon of 23 September 1970. On the last four passes in the afternoon session, both aircraft flew 50 feet above the pinnacle in order to obtain data on aircraft viewed against a sky background.

When each subject, using peripheral vision, could first detect the approaching aircraft, he noted the time on the clock (to the nearest second) and recorded this on a form. When the aircraft passed directly overhead, one designated individual announced the time for each subject to record.

B. AIR-TO-AIR OBSERVATION SEQUENCE (DAYTIME)

Equipment:

- 1) Xenon-flashtube system with three intensity levels;
- 2) Two TH-55 aircraft; and
- 3) Two OH-23 aircraft.

Procedure:

One of the TH-55 aircraft was equipped with the multi-level flashtube lighting system. The other TH-55 was unaltered. The conspicuity of these two TH-55 aircraft was to be compared for different flight altitudes, different intensity levels of the flashtube, and with various backgrounds. Observations were made from the two OH-23 aircraft, each carrying two subjects at a time.

Phase I

The distance between the two TH-55 target aircraft was approximately 50 - 75 feet. The distance from the observation aircraft to the two target aircraft varied considerably but was approximately 125 to 200 feet most of the time. The subjects used a rating scale to compare the relative conspicuity of the two aircraft:

- 0 - no difference in the conspicuity of the two target aircraft
- 1 - lighted aircraft slightly superior
- 2 - lighted aircraft moderately superior
- 3 - lighted aircraft strongly superior

Minus Values could be used to indicate that the standard target aircraft was superior.

The pilots of the test aircraft and observer aircraft flew a similar flight pattern for all subjects. Observations for each of the three light settings were approximately one minute in duration for the different backgrounds. Comparison of the conspicuity of the two test aircraft was made using three different backgrounds:

- 1) Viewing the test aircraft against a ground background;
- 2) Viewing the test aircraft at the same altitude; and
- 3) Viewing the test aircraft positioned above the observation aircraft with a bright sky or cloud background.

Phase II

In this sequence, the observer aircraft approached first the standard-lighted aircraft, and then the strobe-lighted, on a converging mid-air collision course. The subjects were instructed to observe the instrument panel and determine the relative value of the light in attracting their attention and providing visual warning.

Phase III

The final procedure was designed to recreate one of the most common accident-producing attitudes for small trainer helicopters, i. e., two aircraft at different altitudes and either the upper descending upon the lower, or the lower ascending into the upper. This was accomplished by having the TH-55 target aircraft fly side by side with a sufficient rotor separation to allow the observer aircraft to fly from behind and below up between them. The object was for the subjects to maintain fixation on the instrument panel and judge the relative conspicuity of the lighted and non-lighted target helicopters as they moved up between them.

DISCUSSION AND RESULTS

The weather conditions during the study were as follows:

22 September 1970: Winds were 15-18 mph and gusting.
Scattered clouds.

23 September 1970: Due to the effects of a cold front, half of the sky was light gray and the other half was clear and cloudless. Winds calm.

24 September 1970: The sky was clear and cloudless. Winds calm.

Twenty-eight volunteer subjects were utilized as observers during the conduct of the experiment. Fifteen of the subjects were rated aviators and the remaining thirteen subjects were Warrant Officer Candidates who had been selected but not yet begun the Army flight program.

A. GROUND-TO-AIR OBSERVATION SEQUENCE

Both rated (R) and nonrated (N) subjects were used in this experiment. Because we were somewhat limited in the amount of time available to collect all the data, the amount of information we were able to gather was to a certain extent less than ideal. Therefore, we increased the number of data points by ignoring any distinction between N and R in their ability to distinguish the existence of an aircraft.

Contrary to expectations, the N group did slightly better in detecting the aircraft than the R group, indicating that perhaps the study was biased somewhat toward the observers of Group N. Upon looking at the notes taken at the time, it was determined that the N-subjects were inadvertently more concentrated at the small viewing angles than the R-subjects. Thus, there is justification for ignoring the small distinction between the N and R groups and concluding that the group as a whole was a limited but random sample of Army aviators. In all further calculations, except where personal preferences of the subjects for the various systems are given, no distinction will be made between the two groups.

Next, we attempted to determine if the experimental arrangement possessed symmetry between the right and left sides; that is, to show that the subjects on the right were observing under the same physical conditions as those on the left in regards to background, illumination, line-of-sight, etc. To demonstrate this, we took the data from 23 September, when the helicopter did not have the strobe light on, and found the mean time (\bar{X}) for all observers to recognize the existence of the aircraft before it flew directly overhead. This set of data was chosen because it maximized the number of data points and insured uniformity, since by the second day all the observers were familiar with the procedure. Also, weather conditions were more suitable on the second day. On the first day, a fairly strong crosswind kept the pilots from flying the precise assigned course with the result that some erratic responses were obtained.

Utilizing the 72 observations from each side, we found the following results:

$$\text{Right: } \bar{X} = 13.88 \text{ sec.}$$

$$\text{Left: } \bar{X} = 13.53 \text{ sec.}$$

A significance test can now be applied to this information by considering the right side as the standard to which the left must favorably compare in order for

both sides of the experimental arrangement to be equivalent. The confidence interval at the 0.95 probability level was found to be ± 1.04 sec. Since \bar{X} (left) = 13.53 sec. falls well within this range ($\bar{X} = 13.88 \pm 1.04$ sec.), this very strongly suggests that both sides were symmetrical.

With the validity of the experimental arrangement demonstrated, we can now discuss the actual results obtained. Tables II and III give the results of the experiment where all angles and all subjects (N and R) were considered together. For each of the three intensity values we list the following:

- 1) n - the number of observations;
- 2) \bar{X} - the mean value of the time it took from the moment of recognition of the aircraft until it passed directly overhead;
- 3) s - the standard deviation; and
- 4) D - the average increase in distance the aircraft could be detected by equipping it with a high-intensity light.

D was found by multiplying the speed of the aircraft (84.33 ft/sec) by the difference in the recognition times ($\bar{X}_S - \bar{X}_N$), where the subscript "S" refers to the aircraft with the strobe light and "N" refers to the aircraft without the strobe.

It is rather obvious that the use of the strobe greatly enhances the visibility of the aircraft and that the 3300 Eff. Cd. brightness level is the most effective. However, the question of exactly how effective this system is still remains to be answered, as evidenced by the large standard deviations. For the most part, the large standard deviations can be explained by the fact that no distinction was made between the values obtained at the different angles.

The results of Table III are considered more valid than those of Table II, as previously noted. In a more detailed examination of Table III, if we assume that the values obtained for D are constant (given the same brightness level and velocity) for a given type of aircraft, we can find the improvement in time of recognition (Δt) by the following equation:

$$\Delta t = \bar{X}_S - \bar{X}_N = \frac{D}{V}$$

where V is the velocity of the aircraft carrying the appropriate strobe system. Therefore, Δt is inversely proportional to the speed of the approaching aircraft.

Table II (22 Sep 70)

All Angles and Subjects

<u>Level (Eff. Cd.)</u>	<u>w/Strobe</u>	<u>w/o Strobe</u>
3300	$n = 14$ $\bar{X}_S = 30.0 \text{ sec}$ $s = 14.5 \text{ sec}$ $D = (\bar{X}_S - \bar{X}_N) (84.33) = 1,380 \text{ ft}$	$n = 14$ $\bar{X}_N = 13.6 \text{ sec}$ $s = 4.7 \text{ sec}$
2300	$n = 15$ $\bar{X}_S = 31.3$ $s = 15.3$ $D = 944 \text{ ft}$	$n = 15$ $\bar{X}_N = 20.1$ $s = 8.2$
1800	$n = 15$ $\bar{X}_S = 32.3$ $s = 17.0$ $D = 1450 \text{ ft}$	$n = 15$ $\bar{X}_N = 15.1$ $s = 7.9$

Table III (23 Sep 70)
All Angles and Subjects

<u>Level</u> (Eff. Cd.)	<u>w/Strobe</u>	<u>w/o Strobe</u>
3300	n = 48 $\bar{X}_S = 38.69$ s = 16.90 D = 2210 ft.	n = 48 $\bar{X}_N = 12.50$ s = 6.02
2300	n = 48 $\bar{X}_S = 29.23$ s = 14.26 D = 1270 ft.	n = 48 $\bar{X}_N = 14.19$ s = 4.98
1800	n = 48 $\bar{X}_S = 28.10$ s = 15.62 D = 1150 ft.	n = 48 $\bar{X}_N = 14.42$ s = 6.04

It follows from this that for a corresponding increase in the safety factor, a faster aircraft should be equipped with a brighter strobe.

In the previous paragraphs, we considered the results as independent of the various angles. If we consider all subjects with and without strobe according to angle, Figures 3 and 4 provide these results in graphic form. Figure 3 is the breakdown for 22 September 1970, and the results are not what was expected. The weather conditions were not conducive for obtaining meaningful results. For example, in Figure 3 it is certainly not obvious that the 3300 level strobe yields the best performance. However, with only 2 or 3 subject responses for each point on the graph, large numerical deviations can be expected. The important thing to note here is that the strobe light definitely improved the visibility of the aircraft.

Figure 4 shows the results from 23 September 1970. Throughout this day, weather conditions were better and the observers more experienced; thus the results were closer to what might be expected. The fact that we also had three times as many responses than the previous day also increases the significance of Figure 4. The only unexpected occurrence here takes place at the 60° position. According to theory, the graph of time (\bar{X}) as a function of angle should show a uniform decrease as the angle increases. Since this is the maximum viewing angle, we can only assume that someone at this position was not keeping his eyes fixed on the target. This is quite possible because there were only two people at this position; if one of them turned his head to look directly at the aircraft, the mean value \bar{X} would be greatly affected.

The previous discussion has dealt with the visibility of aircraft against a relatively dark "ground" background. The results of using the strobe at the 3300 level against the bright sky background can be seen in Table IV.

Table IV
All Angles and Subjects
(23 Sep 70)

3300 Eff. Cd. Level w/Sky Background

<u>w/Strobe</u>	<u>w/o Strobe</u>
$n = 32$	$n = 31$
$\bar{X}_S = 33.5 \text{ sec.}$	$\bar{X}_N = 29.0 \text{ sec.}$
$s = 15.4 \text{ sec.}$	$s = 13.4 \text{ sec.}$

ALL SUBJECTS-22 SEPT., 1970

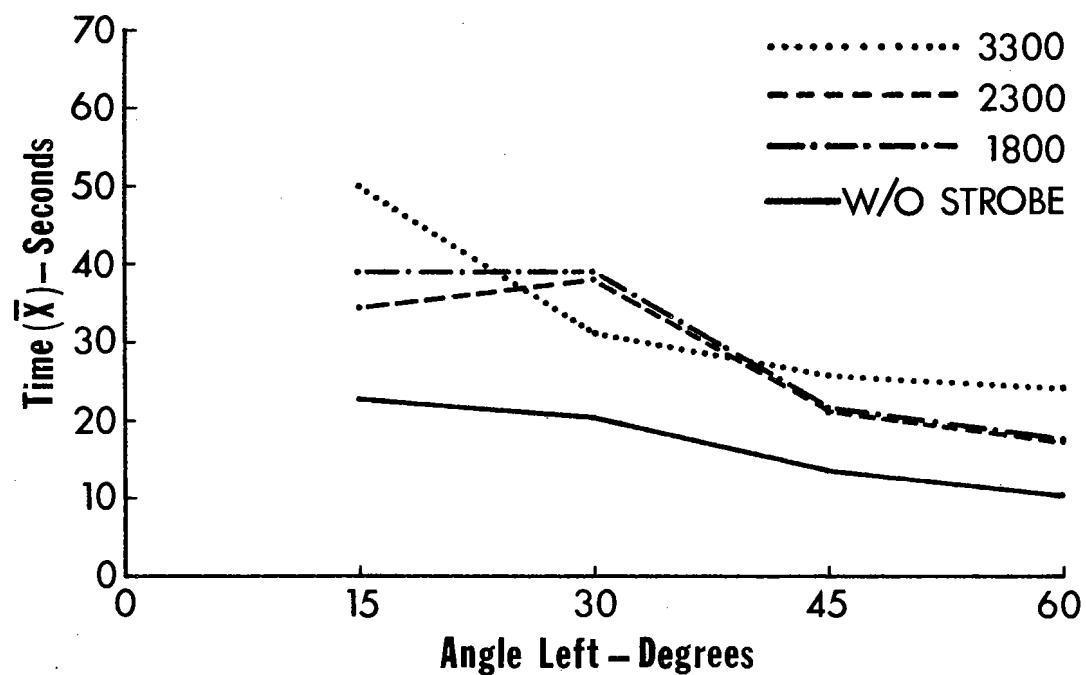
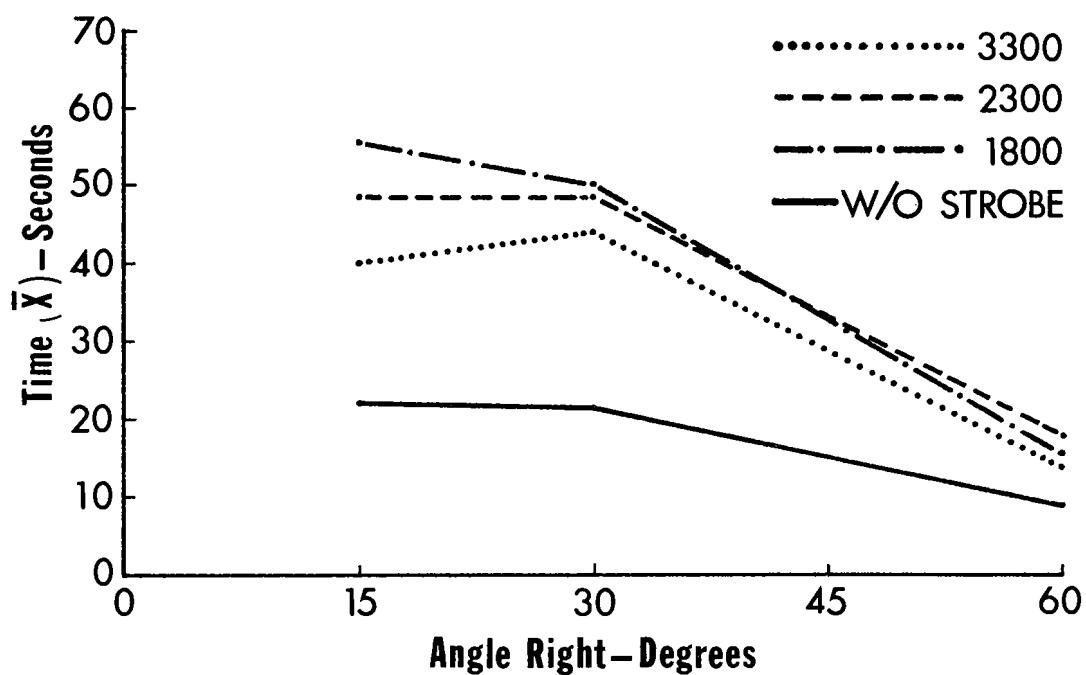


Figure 3.

ALL SUBJECTS - 23 SEPT., 1970

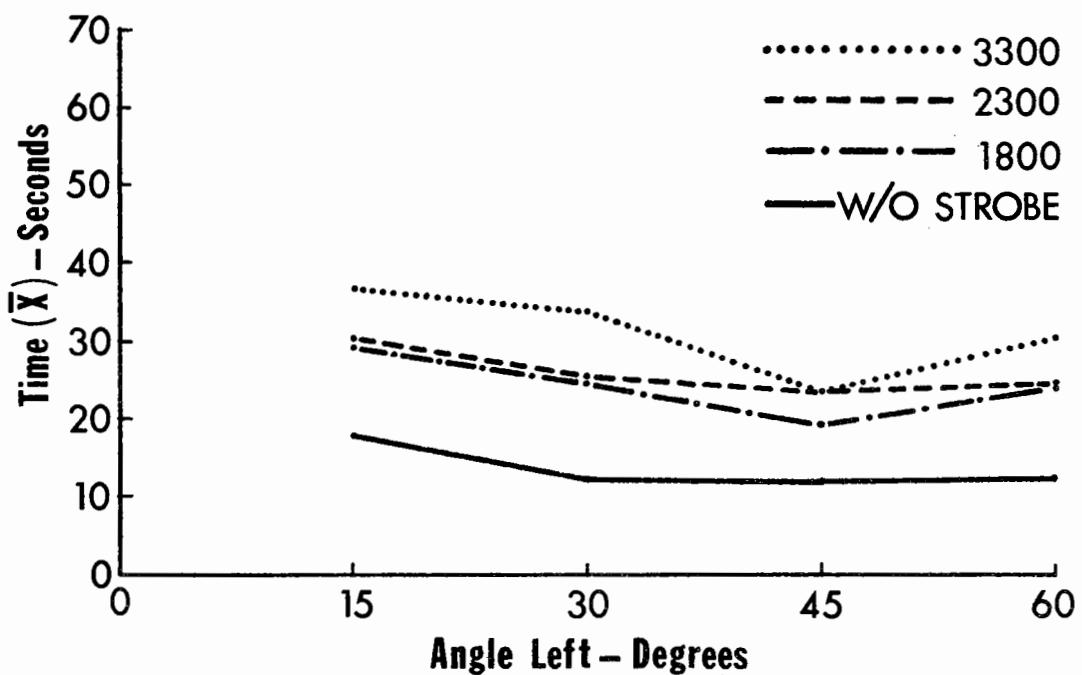
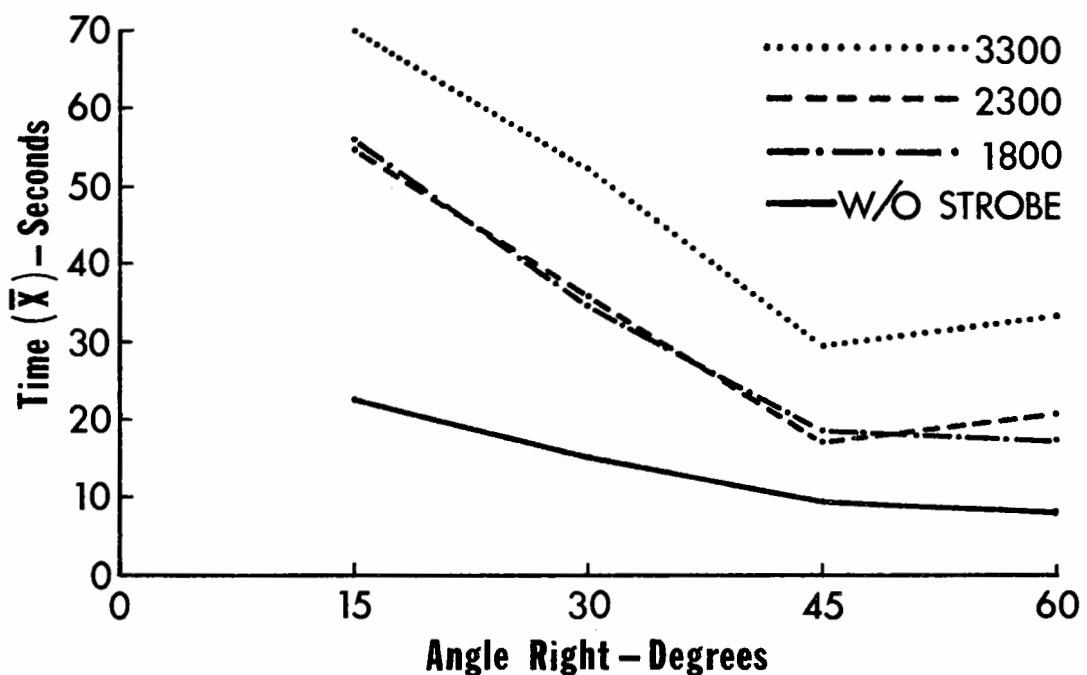


Figure 4.

Very little difference is apparent in the two results. This is to be expected since the contrast between the day sky and the strobe is much less than that between the strobe and the ground.

B. AIR-TO-AIR OBSERVATION SEQUENCE (DAYTIME)

Phase I

The results of Phase I are outlined in Table V. As noted in the Methodology section, the observations were made in-flight with the target aircraft being viewed against a ground background, against a horizon background (aircraft on the same level), and against a sky background (above). These observations were made at all three intensity levels.

It will be noted that the number of observations in Phase I differ between light intensity levels. The reason for this is the fact that on 22 September we completed the pinnacle runs in the morning, but were unable to fly in the afternoon due to high winds. On 23 September, the in-flight studies were conducted in the morning, but due to a failure of radio communication between target and observer aircraft, the subjects could not be notified that a change in intensity levels was being made. It was decided to leave the highest level in operation and disregard the lower levels on that day. We were successful in reestablishing radio contact the following day, and observations were made at each intensity level.

Phase II

The results of Phase II are shown in Table V. The aircraft were converging in a simulated mid-air collision.

Phase III

The results of Phase III are also shown in Table V. The observer aircraft approached the target aircraft from below and to the rear. They then flew up between them in an attempt to reconstruct a common mid-air collision situation involving helicopters in the training environment.

C. NIGHT LIGHTING

Two off-the-shelf white Xenon lamps, each having an output of approximately 300 - 400 effective candelas, were mounted on a TH-55 helicopter at

Table V
In-Flight Preference Study

		Phase I						Phase II		Phase III	
		Ground		Level		Above		Converging		From Below	
		R	N	R	N	R	N	R	N	R	N
3300	P	2.68	2.28	1.97	2.05	1.36	1.65	2.33	2.10	1.61	1.90
Level	n	54	40	54	40	54	40	27	20	27	20
2300	P	2.00	2.10	2.00	2.00	1.62	1.30				
Level	n	13	10	13	10	13	10				
1800	P	1.77	1.90	1.69	1.70	1.38	1.30				
Level	n	13	10	13	10	13	10				

Rating Scale

- 0 - no difference in conspicuity of lighted and non-lighted aircraft.
- 1 - lighted aircraft slightly superior.
- 2 - " " moderately "
- 3 - " " strongly "

P - mean value of preference

n - number of observations

Fort Wolters, Texas. Four pilots flew the aircraft during all phases of normal night operations. The responses were unanimous that the problem of backscatter was too severe. Light reflections in the cockpit, particularly during the hover mode, were very annoying.

Following the procurement of two more Xenon lamps, each having a red light output of approximately 100 to 200 effective candelas, investigators from this Laboratory again returned to Fort Wolters. Three pilots flew a TH-55 equipped with this red lighting while additional observations were made both from the air and on the ground. There were absolutely no problems with this system concerning backscatter. This was to be expected since the peripheral portion of the retina of the eye is less sensitive to a red than to a white stimulus. The visibility characteristics were considerably better than the standard rotating beacon for three reasons. First, the light distribution above and below the horizontal plane was 60 degrees instead of 30 degrees, and the loss in light output at these extremities was 25 percent versus 90 percent for the rotating beacon. Second, the rapid flash characteristics of the Xenon were more conspicuous. Third, the Xenon lamp radiates a full 360 degrees with each flash, rather than the sweeping motion of the beacon.

Subsequent in-flight evaluations at Fort Rucker with the TH-13 helicopter and four rated pilots confirmed the results found at Fort Wolters.

CONCLUSIONS

This study provides the first known in-flight data pertaining to the enhancement of helicopter daytime visibility through the application of high-intensity lighting. The results indicate that the lights provided a very significant increase in sighting distances of aircraft, especially when viewed against a ground background. All of the subjects considered the lighting system superior under a variety of viewing conditions.

Future studies are anticipated in an effort to further define the degree of enhancement associated with viewing different lighting systems under varying conditions.

REFERENCES

1. Marty, M. L. CW2, and Spivey, L. B. CW3. "Army Midair Collision," prepared by The U. S. Army Board for Aviation Accident Research, Report No. 71-1, 1970.
2. Whiteside, T. C. D. "The Problem of Vision in Flight at High Altitude," Butterworths Scientific Publications, London, 1957.
3. United Air Lines - Air Line Pilots Association. Joint Crew Complement Evaluation: Summary of Results Report, 1968.
4. Bynum, James A.; Bailey, Robert W.; Crosley, John K.; and Nix, M. S., Jr. "Development of a Paint Scheme for Increasing Helicopter Conspicuity," U. S. Army Aeromedical Research Unit, Ft. Rucker, Alabama, USAARU Report No. 68-1, September 1967.
5. Crosley, John K.; Bailey, Robert W.; and Nix, M. S., Jr., "Improving Helicopter Conspicuity Through the Use of Painted Main Rotor Blades," U. S. Army Aeromedical Research Unit, Ft. Rucker, Alabama, USAARU Report No. 68-2, October 1967.
6. Projector, T. H. "The Role of Exterior Lights in Mid-Air Collision Prevention," FAA/BRD-127 (1962).
7. Howell, W. D. "An Investigation of Some Means to Improve the Daytime Conspicuity of Aircraft," CAA Tech. Report No. 344 (1958).
8. Morris, E. W. and Gerathewohl, S. J. "Anticollision Lights for Supersonic Airplanes," Working Paper for FAA (1967).
9. Bauer, R. W. and Barnes, J. A. "Human Factors in Anticollision for VTOL and V/STOL Aircraft," U. S. Army Human Engineering Laboratories Letter Report No. 64 (1967).
10. Land, Peter L. "A Discussion of the Use of Xenon Flash Lamps for Anticollision Purposes," USAF Aerospace Research Laboratory Report No. 70-0083, Project No. 7021 (1970).

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13. ABSTRACT <p>In-flight studies were performed at Fort Wolters, Texas, to compare the effectiveness of aircraft-mounted, high-intensity Xenon flashtube lights for increasing the conspicuity of small trainer helicopters (TH-55) during both daytime and nighttime flights. Twenty-eight subjects rated both lighted and non-lighted aircraft visibility as viewed from the ground and from air to air in differing flight modes. Data are presented to indicate the increase in aircraft conspicuity available through the application of this type of lighting.</p>		

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